National Aeronautics and Space Administration

Characterizing Near-surface Fractures in Radar Interferograms

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With thanks to NASA programs:

Advanced Information Systems Technologies, Earth Surface and Interior

Applications of Geodetic Imaging, Decision Support Through Earth Science Research Results

Topics

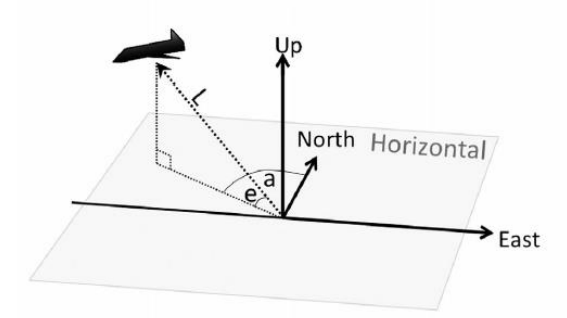
- UAV Synthetic Aperture Radar (Repeat Visits)
- Importance of characterizing secondary faulting
- Gain and risk from multiple views
- Pseudomechanism, wide composite views
  - Napa, SAF
- Automatic scanning for
  - mechanism, shear width, total slip

UAVSAR Pod On Gulfstream III

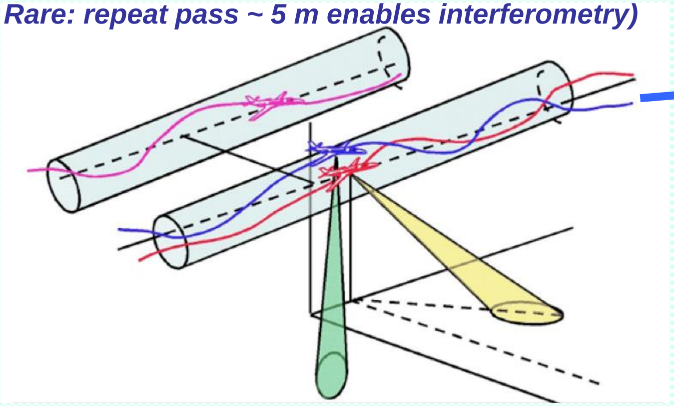
***Gulfstream 3 semi-piloted** aircraft*

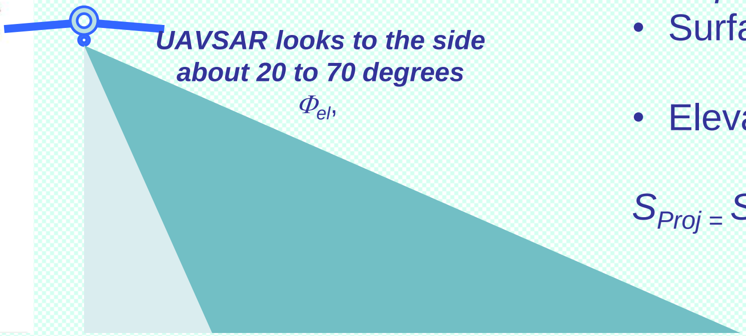
- Radar for studying earth processes
- **Repeat visit→ landscape *change* image**
- High-definition: 7 m pixel size:
- >120 Megapixel images
- Sensitive: sees <1 cm surface fault slip

One day on Global Hawk or other drone?



Rare: repeat pass ~ 5 m enables interferometry)





UAVSAR looks to the side about 20 to 70 degrees Φ_{el},

- *Repeat Pass Interferometry:*
- Surface deformation, mapped into
- Elevation Φ_{el}, azimuth θ_{Az} (Line-Of-Sight)

$S_{Proj} = S \cos(\Phi_{el}) \cos(\theta_{Az} - \theta_{Strike})$

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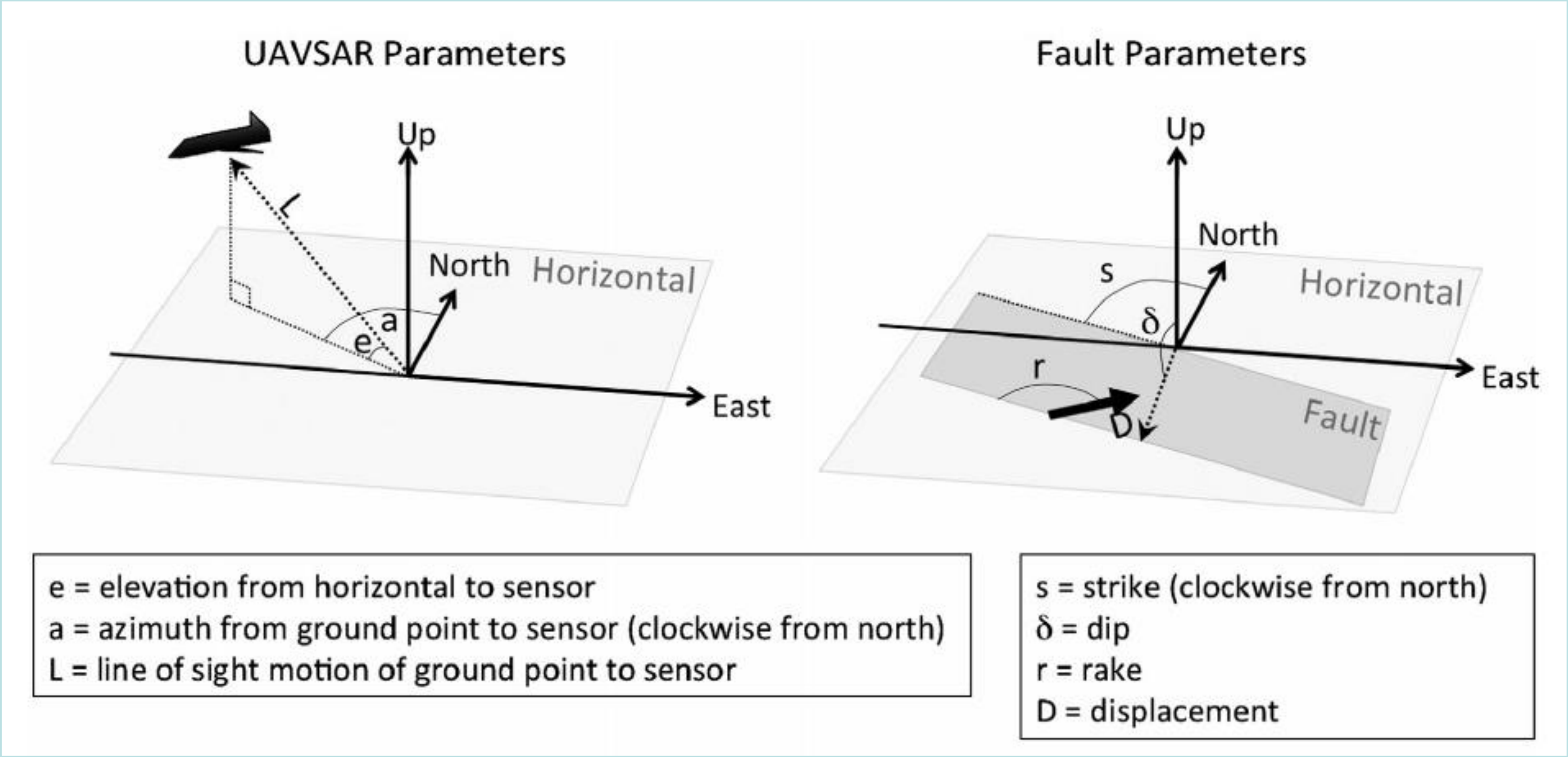
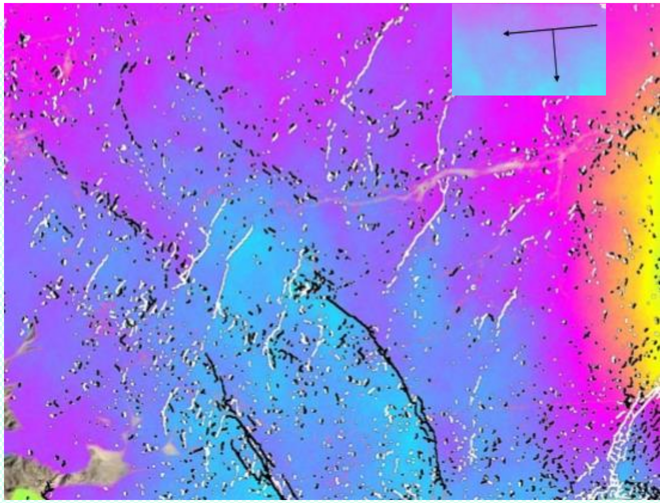
Slip vs LOS slip

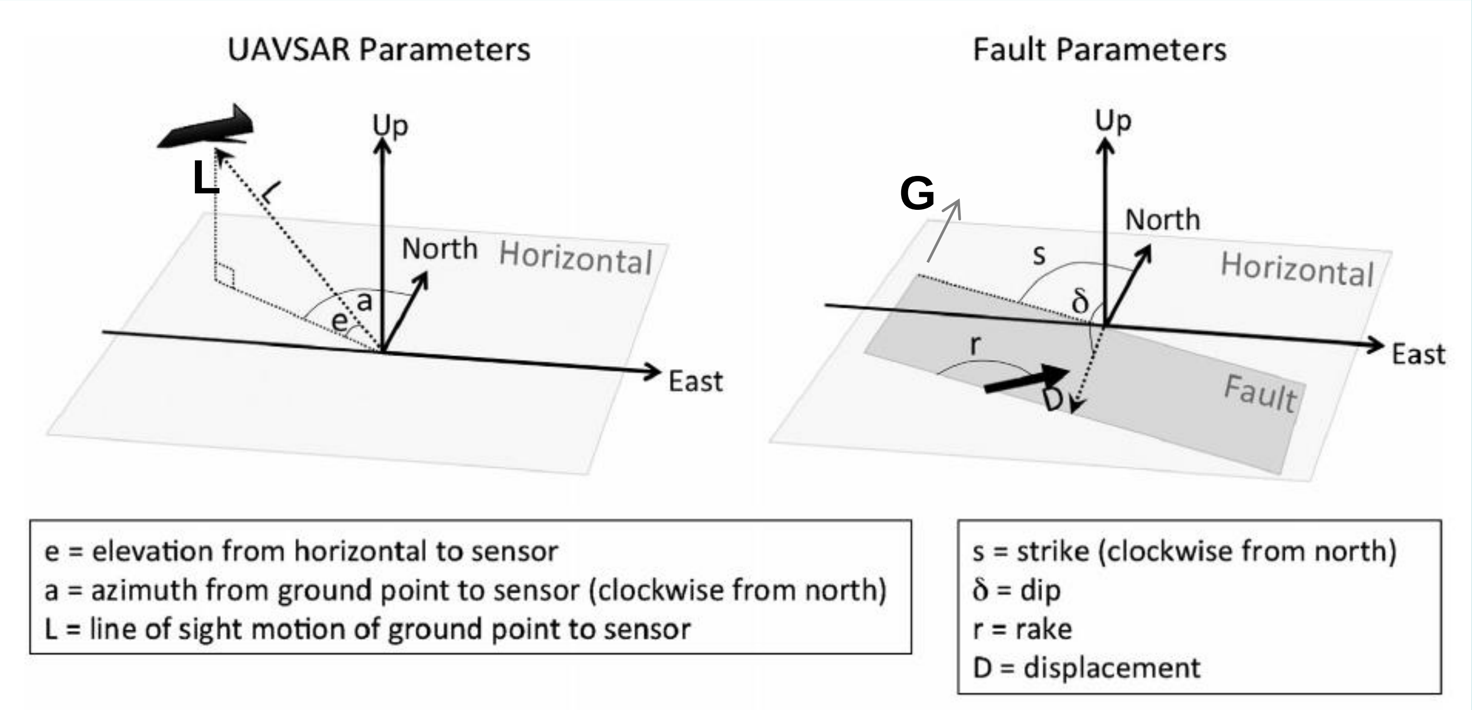
- Slip vs. Line Of Sight (LOS) projected slip
- For true strike slip D = 100mm, reduce by $D_{LOS} = D \cos(a - s) \cos(e)$,
- Example: $a - s = 45$, $e = 45 \Rightarrow D_{LOS} = 50$mm



PseudoMechanism

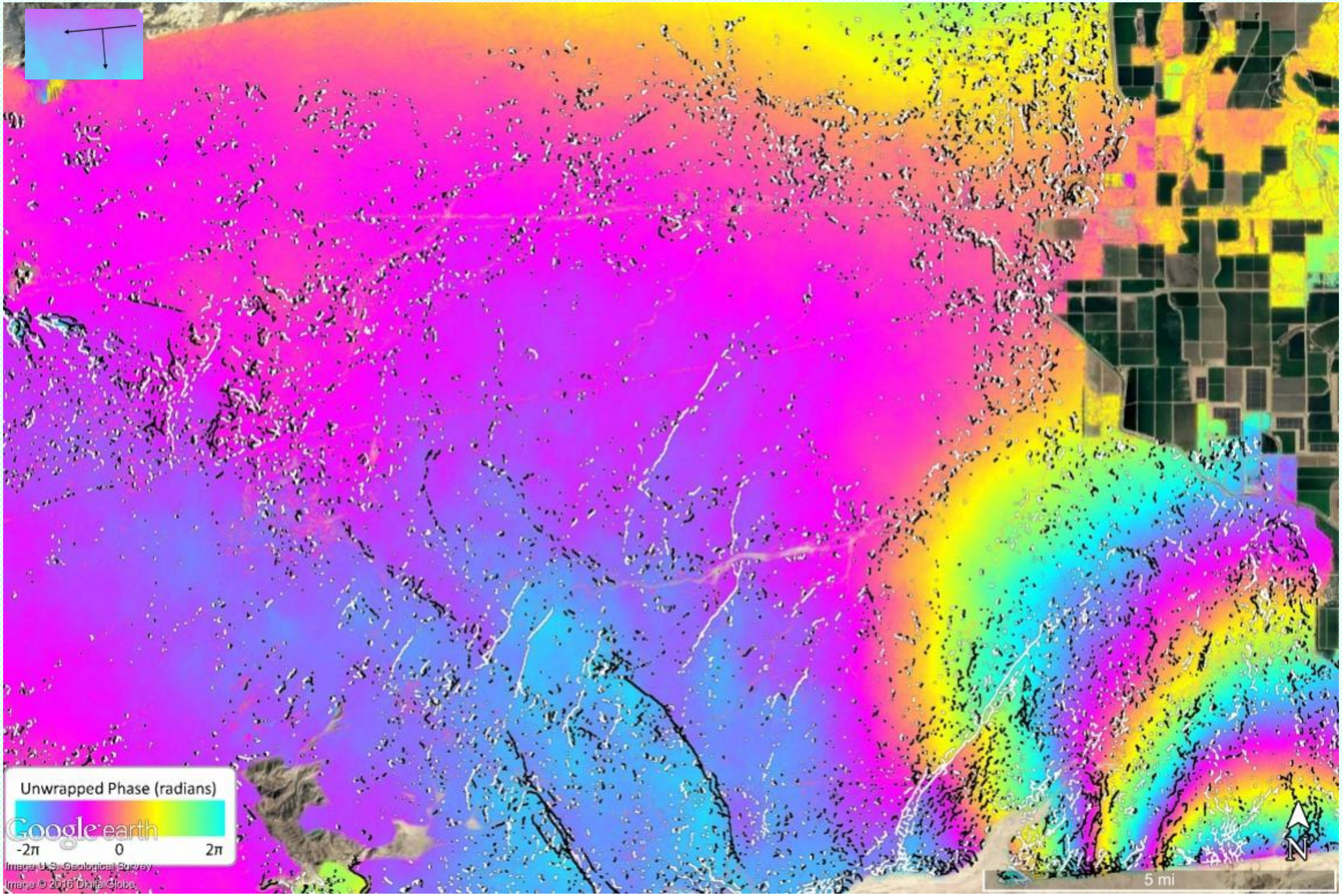
- Radar sees rupture as a value jump across a line
- One side moves closer, one side farther
- Gradient **G** direction shows which moved closer
- Sign of **G** x **L:**
  - + white pseudo left lateral (pLL)
  - - **black** pseudo right lateral (pRL)
  - (*but could have vertical part*)



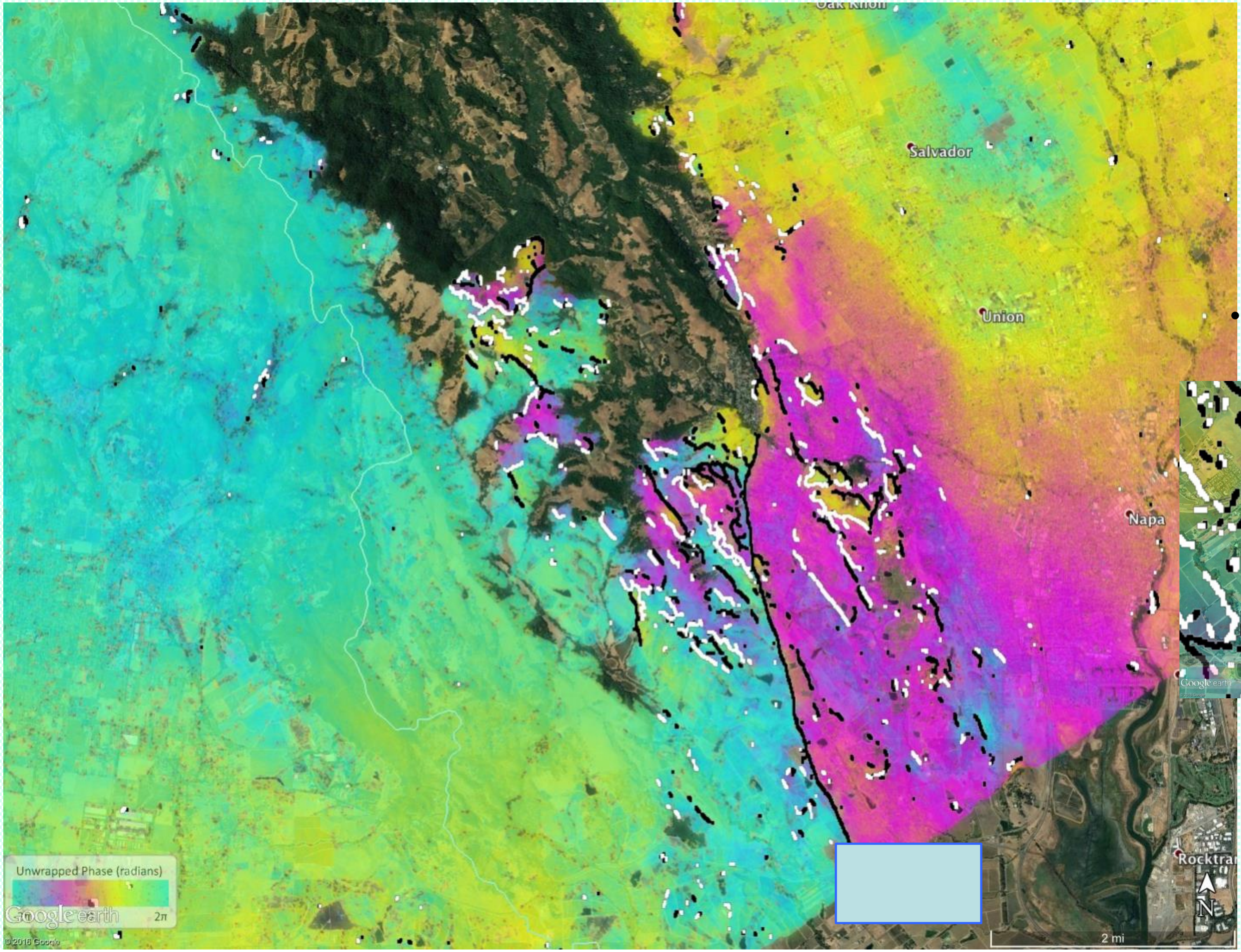


Border CA-MX visits Oct 2009 : Sep 2010

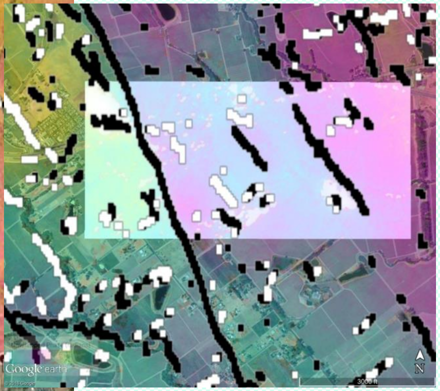
EMC occurred April 4 2010



South Napa Earthquake, line 05512

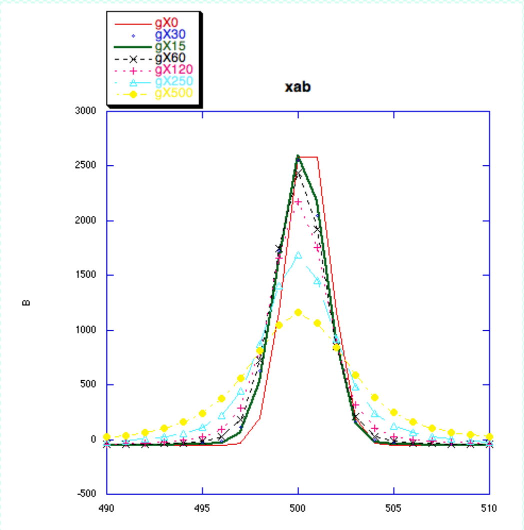


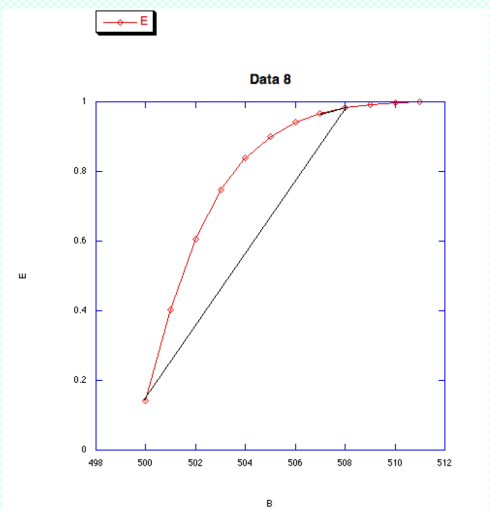
- View from north: line 23511

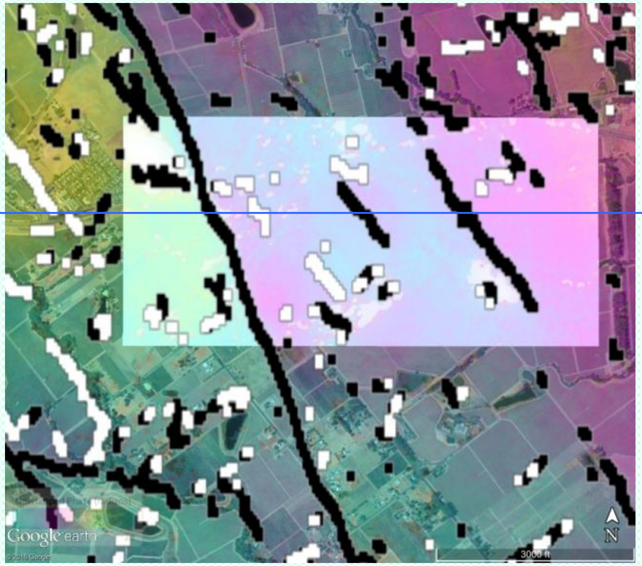


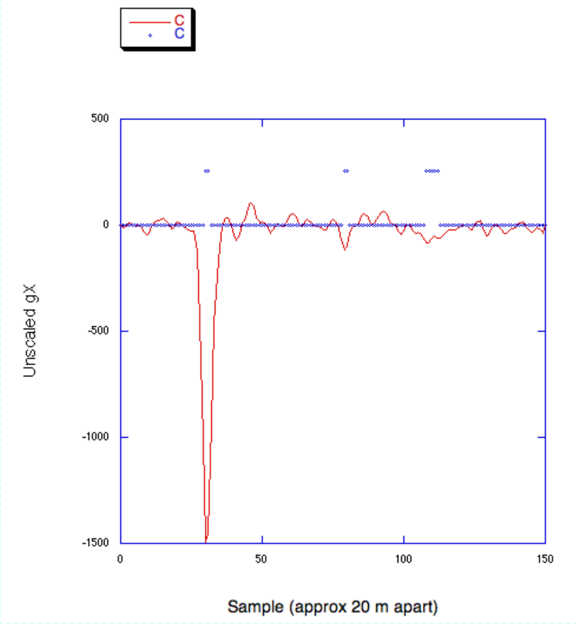
Evaluation of slip, Napa sample

- Gradient across fault
- Simulated (Okada elastic half-space)
- Varying fault top (locked above this), 0-500m for dx = 200m
- Sum across width -> consistent total slip
- Width: how? Currently by slope ratio threshold (left)



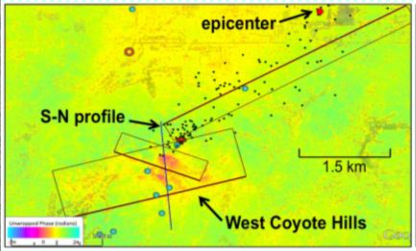


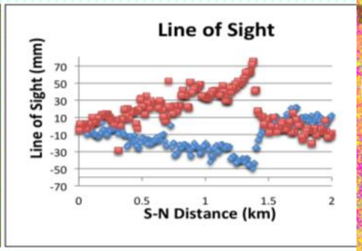


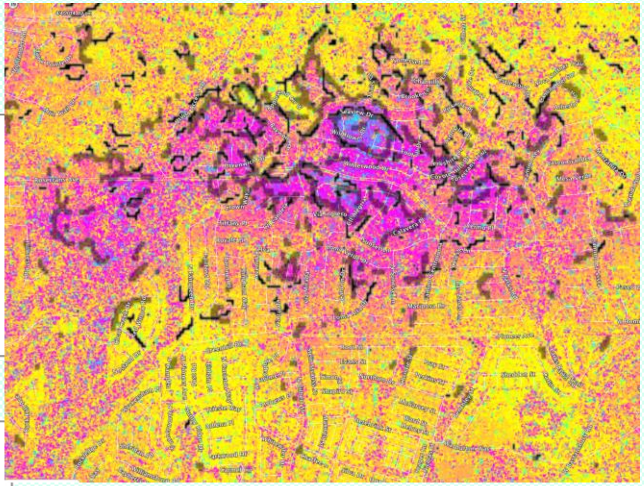


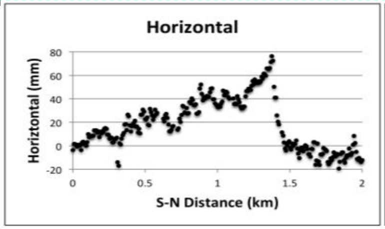
Two views: what can we learn?

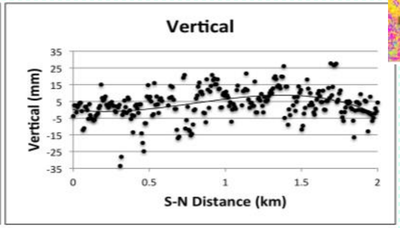
- Two views: separation of vertical slip from horizontal.
- Vector analysis yields clean separation of one vertical and one horizontal slip component. (bottom row, from Donnellan et al, 2015).
- H ~ Z x B, V~ BxH. Express L1, L2 in this basis: L1h, L1v etc. Deformation jump components are then
- dD1= Sh L1h + Sv L1v =➔ solve for horizontal, vertical slip components Sh, Sv.
- dD2= Sh L2h + Sv L2v   (automation in progress).
- La Habra earthquake M5.1 3/28/2014 damage area:



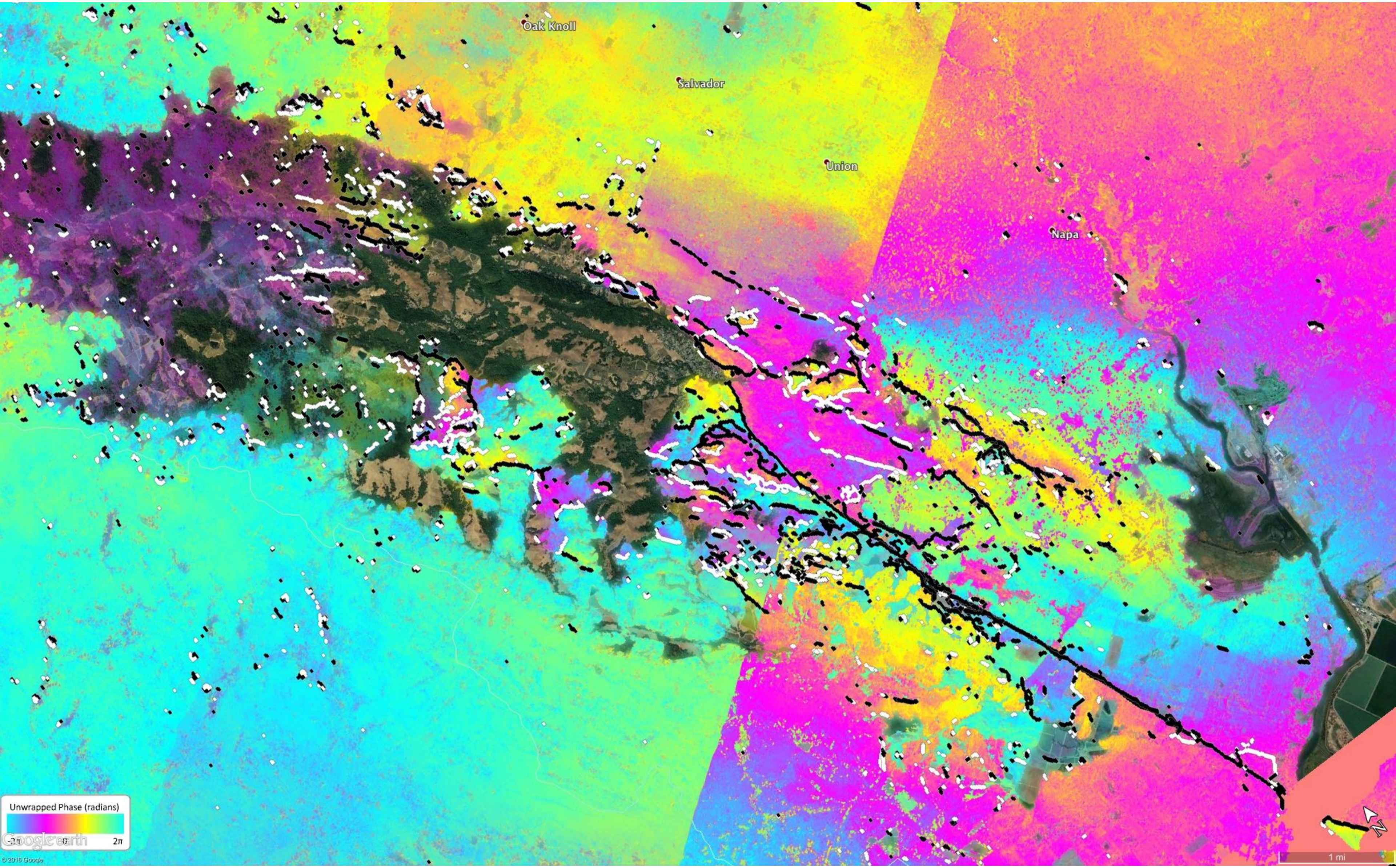




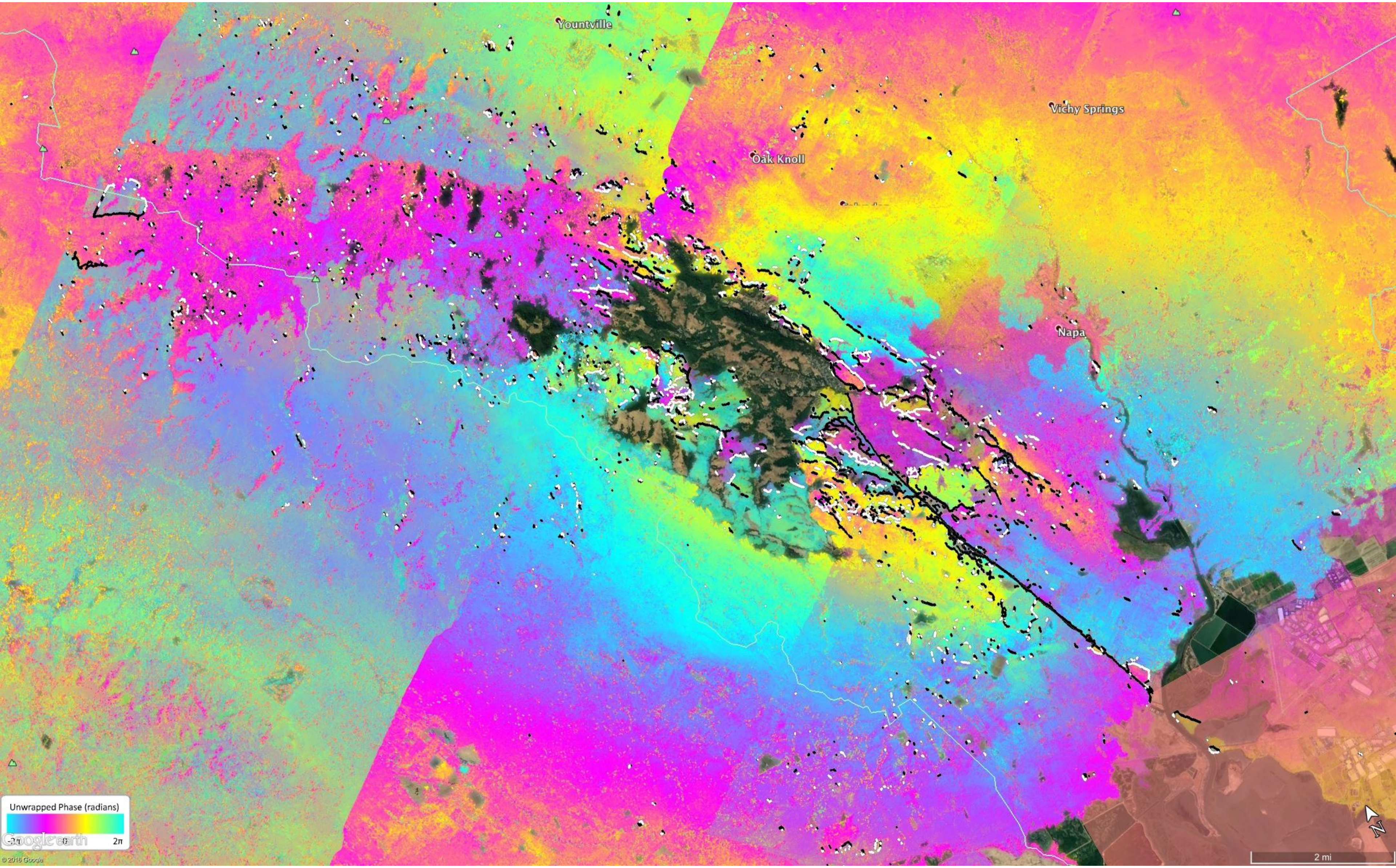




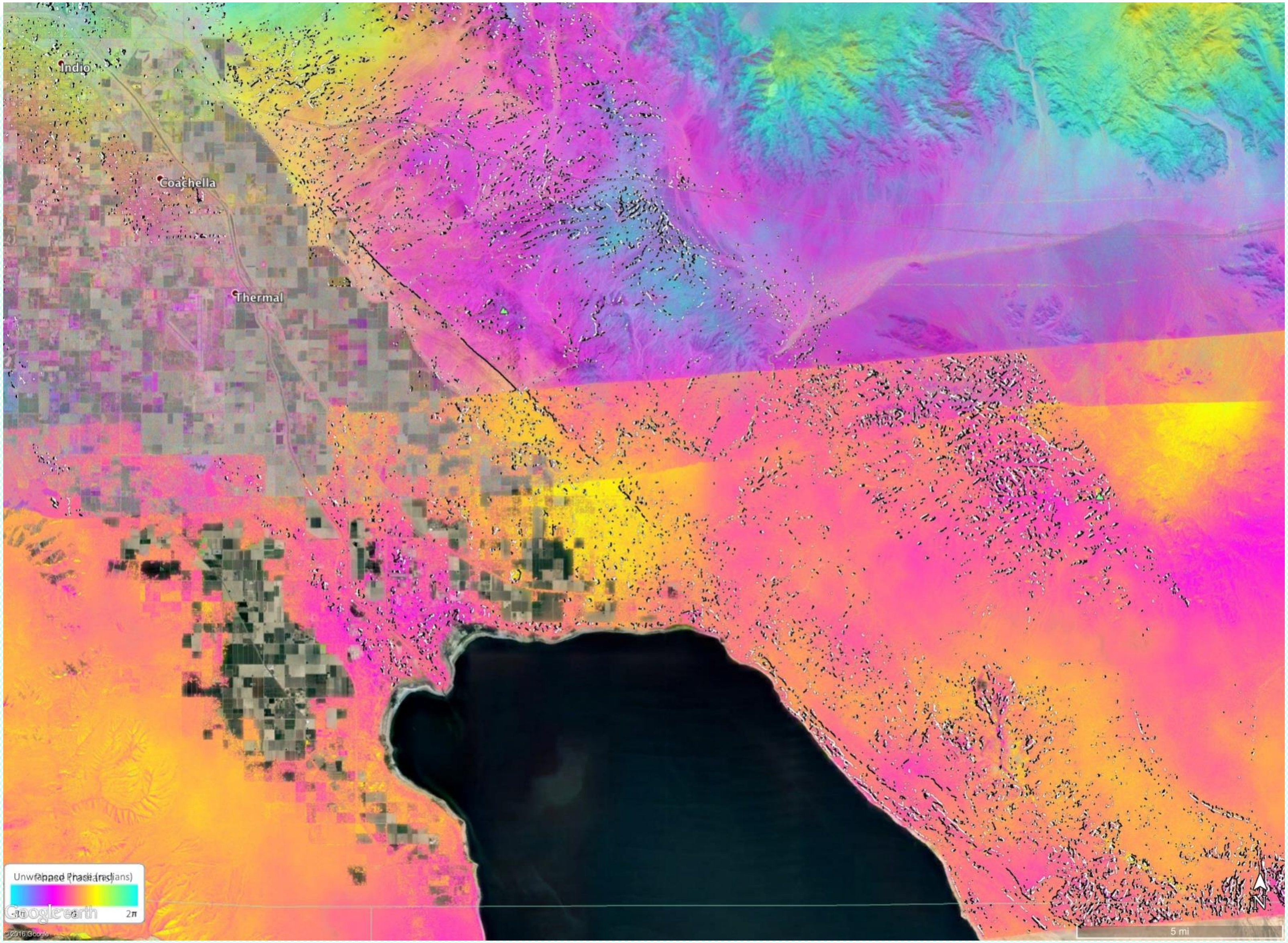
South Napa Earthquake, Composite



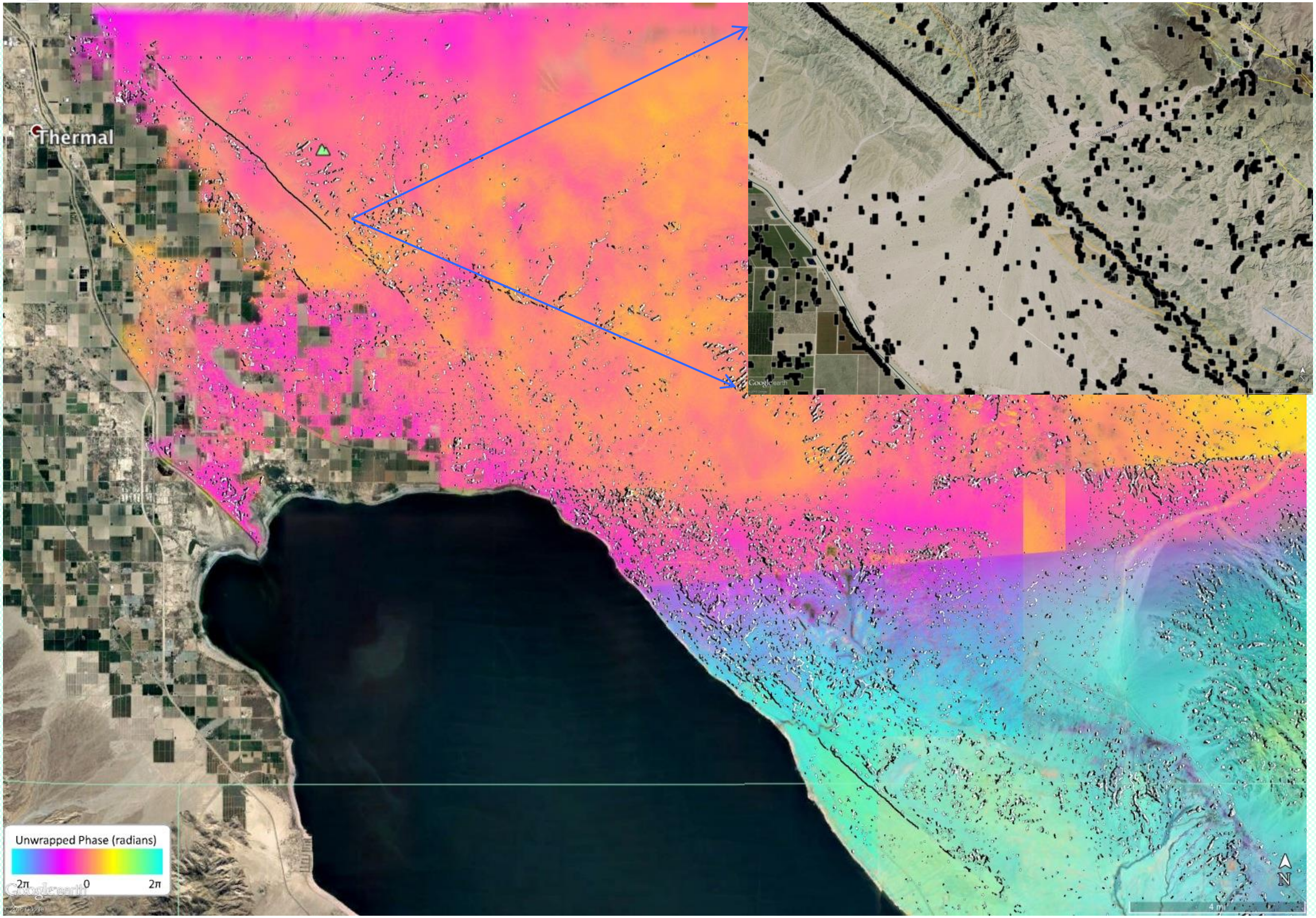
South Napa, wider view



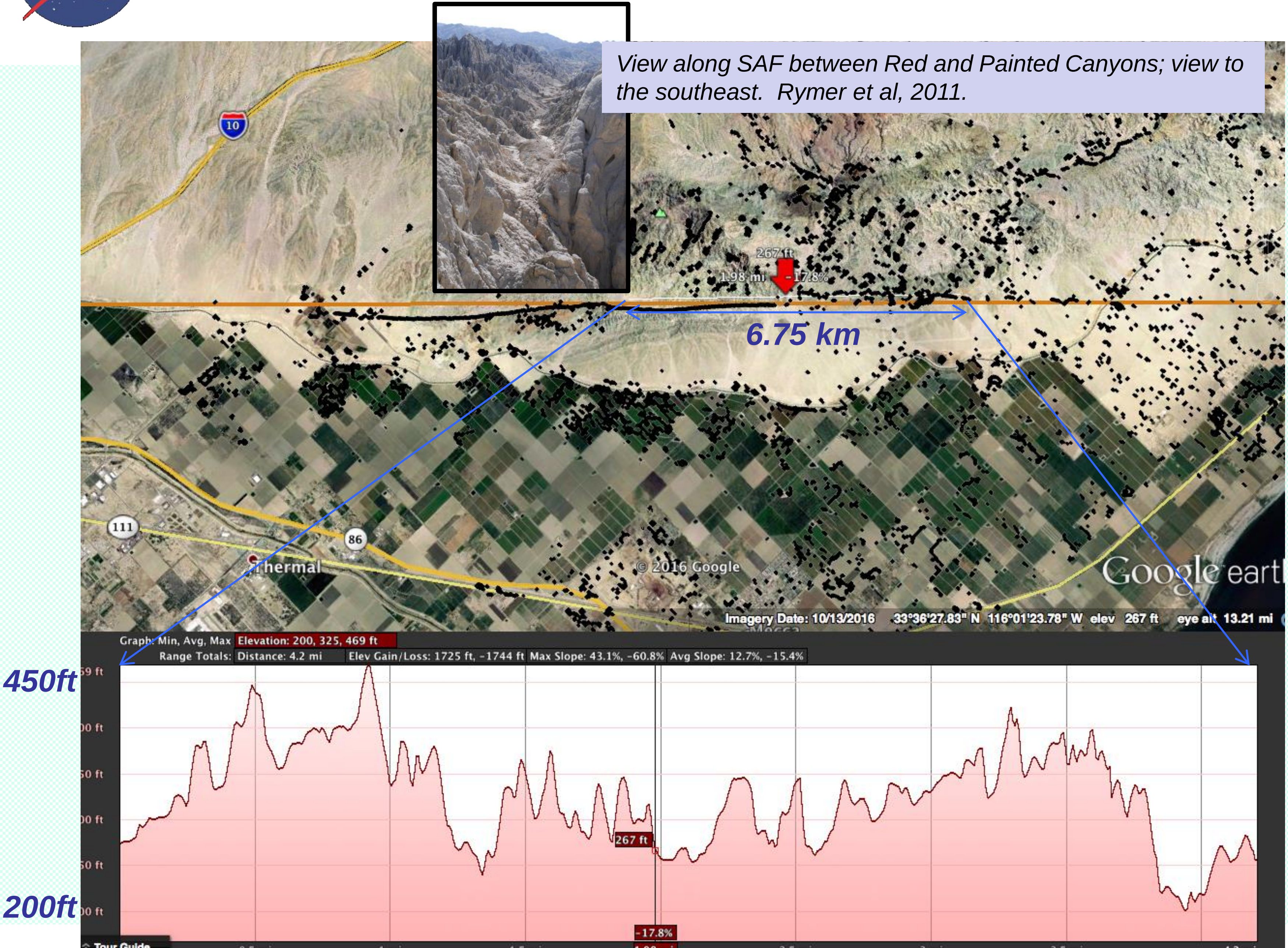
SAF triggered by EMC:
from south



San Andreas Fault triggered by EMC
from north



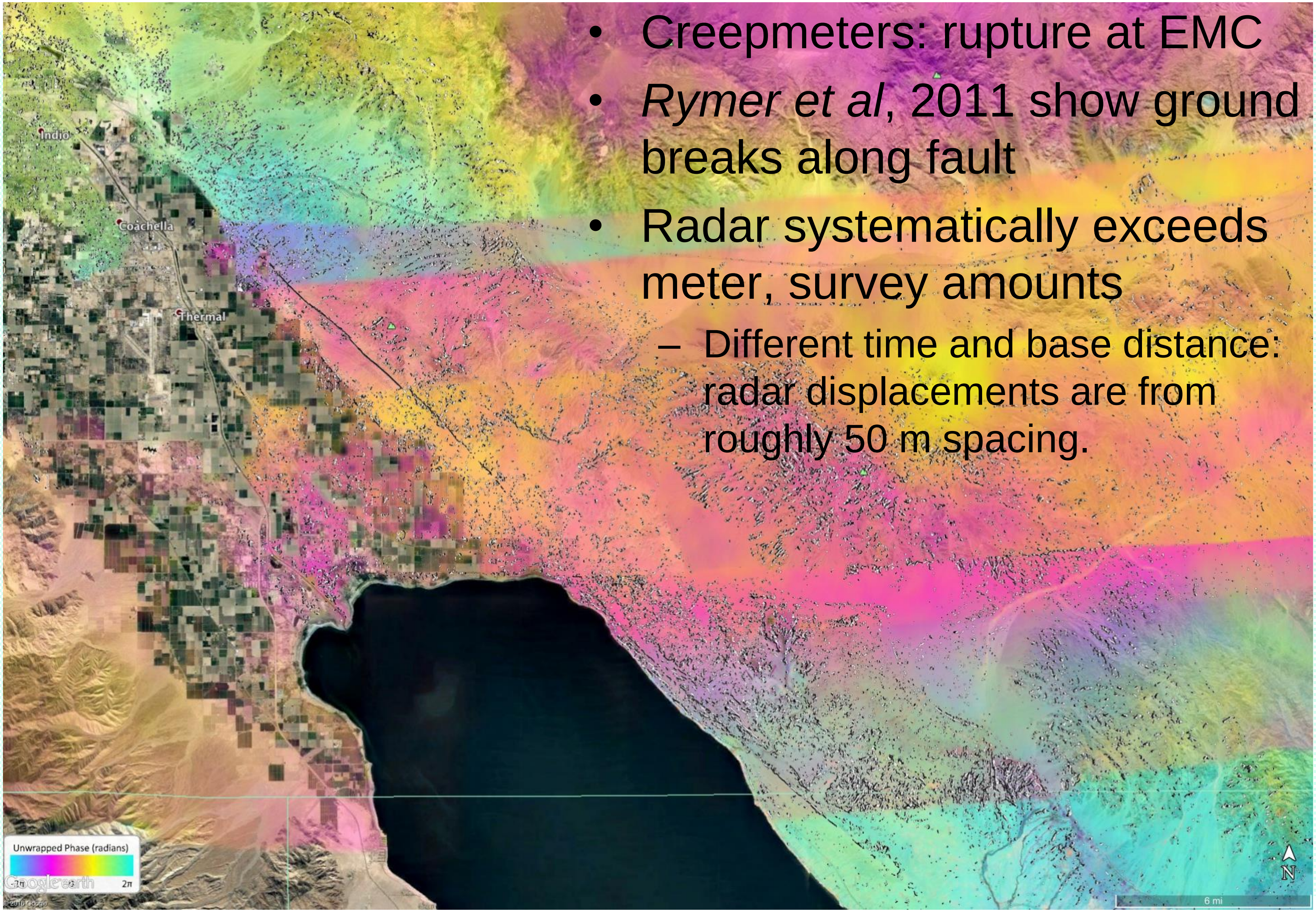
Detail: Painted Canyon, Mecca Hills



View along SAF between Red and Painted Canyons; view to the southeast. Rymer et al, 2011.

SAF triggered by EMC, composite, 5 strips

- Creepmeters: rupture at EMC
- *Rymer et al*, 2011 show ground breaks along fault
- Radar systematically exceeds meter, survey amounts
  - Different time and base distance: radar displacements are from roughly 50 m spacing.



Next Steps, Conclusions

Next Steps

- Automate total displacement, shear width
- Extend to wrapped interferograms
- Demonstrate using satellite InSAR

Conclusions

- Detecting edge pixels allows large reduction in further analysis (typically 1m total to 5k points of interest)
- Maps of pLL, pRL show patterns of tectonic development
- Composite maps of pLL, pRL with several strips make large approximations but show helpful big picture